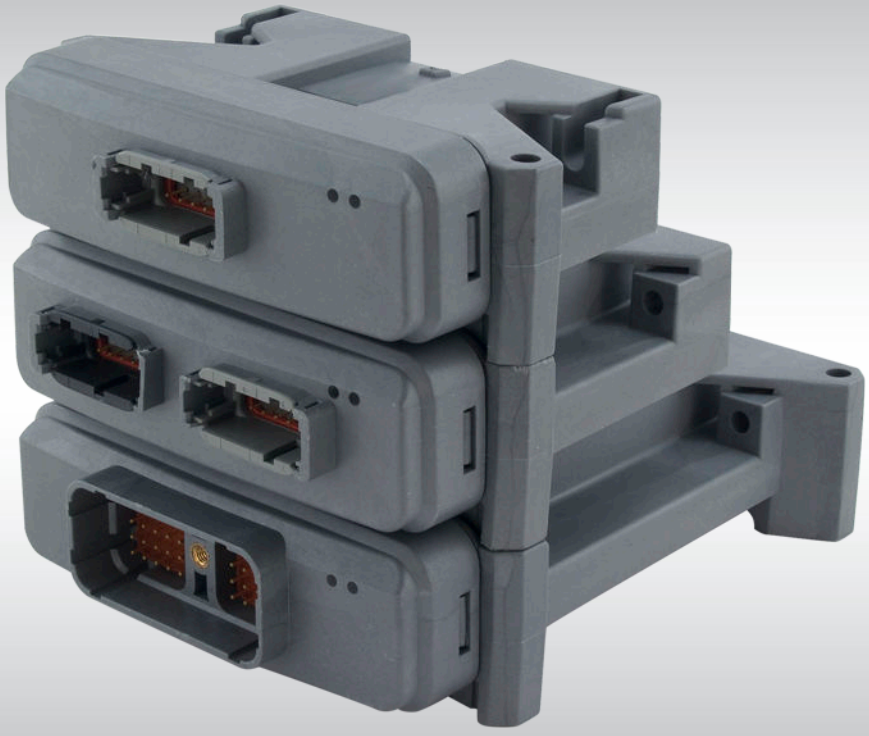
MAKING MODERN LIVING POSSIBLE

Technical Information

PLUS+1®
Controller Family



Revision history

Table of revisions

Date	Changed	Rev
May 2015	Revised note regarding pin C1p26	QA
February 2014	MC050-055/05B input voltage maximum is limited to 16 Vdc	PB
January 2014	Converted to Danfoss layout	PA
June 2005 to September 2013	Various updates	BA through OA
March 2004	First edition	AA

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PLUS+1® Controller Family Technical Information

This manual is designed to be a comprehensive PLUS+1® product family hardware module reference tool for vehicle OEM design, engineering, and service personnel. It is one of four sources of PLUS+1® product technical information. Other sources include individual module product data sheets, module specific *Application Program Interface (API) specifications* and the *PLUS+1® GUIDE User Manual*, *10100824*. Danfoss product literature is online at: *http://powersolutions.danfoss.com/literature/*

What information is in this manual?

This manual describes unique characteristics of specific PLUS+1® modules and electrical details that are common to all PLUS+1® modules, including general specifications, input and output parameters, environmental ratings and installation details.

What information is in individual module product data sheets?

Parameters that are unique to an individual PLUS+1® module are contained in the module product data sheet. Data sheets contain the following information:

- Numbers and types of inputs and outputs
- Module connector pin assignments
- Module maximum current capacity
- Module sensor power supply (if present) current capacity
- Module installation drawing
- Module weights
- Product ordering information

What information is in individual module API specifications?

Detailed information about the module BIOS is contained in the module API specification. PLUS+1® BIOS functionality is pin dependent. Pins are defined in module data sheets as C (connector number) p (pin number). API specifications include:

- Variable name
- Variable data type
- Variable direction (read/write)
- Variable function and scaling

Module API specifications are the definitive source of information regarding PLUS+1® module pin characteristics.

PLUS+1® GUIDE User Manual

This user operation manual (OM) details information regarding the PLUS+1® GUIDE tool set that is used to build PLUS+1® applications. This OM covers the following broad topics:

- How to use the GUIDE graphical application development tool to create machine applications
- How to configure module input and output parameters
- How to configure module input and output parameters
- How to download GUIDE applications to target PLUS+1® hardware modules
- How to upload and download tuning parameters
- How to use the PLUS+1® Service Tool

Overview

PLUS+1® Family of Mobile Machine Management Products

12, 18, 24, 38, 50, and 88 pin models

F101 753

PLUS+1® controllers and input/output expansion modules are designed to provide flexible, expandable, powerful, and cost effective total machine management systems for off-highway vehicles. These modules communicate with one another and other intelligent systems over a machine Controller Area Network (CAN) data bus. PLUS+1® hardware products are designed to be equally effective in a distributed CAN system, with intelligence in every node, or as stand-alone control for smaller machine systems. PLUS+1® systems are incrementally expandable: additional modules can be easily added to the machine CAN bus to increase system capabilities or computational power.

PLUS+1® control products utilize modular designs wherever possible. This modularity extends to product housings, connectors and control circuitry. Six standard housings, 12, 18, 24, 38, 50, and 88 pin, cover the entire product line.

User liability and safety statements

OEM responsibility

The OEM of a machine or vehicle in which Danfoss products are installed has the full responsibility for all consequences that might occur. Danfoss has no responsibility for any consequences, direct or indirect, caused by failures or malfunctions.

- Danfoss has no responsibility for any accidents caused by incorrectly mounted or maintained equipment.
- Danfoss does not assume any responsibility for Danfoss products being incorrectly applied or the system being programmed in a manner that jeopardizes safety.
- All safety critical systems shall include an emergency stop to switch off the main supply voltage for the outputs of the electronic control system. All safety critical components shall be installed in such a way that the main supply voltage can be switched off at any time. The emergency stop must be easily accessible to the operator.

Inputs/outputs types and specifications

Each PLUS+1® hardware module has input or output pins that support multiple functions. Pins that support multiple input or output types are user-configurable using PLUS+1® GUIDE software. Refer to controller data sheets for the input/output (I/O) content of individual modules.

Inputs

Input functional types

- Digital (DIN)
- Digital or Analog (DIN/AIN)
- Analog or Temperature or Rheostat (AIN/Temp/Rheo)
- Multifunction: Digital or Analog or Frequency (DIN/AIN/FreqIN)
- Multifunction: Digital or Analog or Frequency or Rheostat (DIN/AIN/FreqIN/Rheo)
- Fixed Range Analog or CAN shield (AIN/CAN shield)
- Digital or Analog or Current (DIN/AIN/4-20 mA IN)

Each PLUS+1® module input pin supports one of the above functional types. For pins with multiple functions, input configurations are user programmable using PLUS+1® GUIDE templates.

DIN

Digital inputs (DIN) connected to PLUS+1® dedicated digital input pins are debounced in software. Digital input debounce is defined as an input being in a given state for three samples before a state change is reported. The sample time is a function of application loop time.

Multifunction pins that are configured to be DIN are subject to the same update rates as the analog input function for that pin. Debounce is not used, as hysteresis is built into the function. The time to recognize a transition is dependent on the timing of the switch activation and the sample rate.

General

Description	Comment
Response to input below minimum voltage	Non-damaging, non-latching; reading saturates to the low limit.
Response to input above maximum voltage	Non-damaging, non-latching; reading saturates to the high limit.
Response to input open	Pin configuration dependent: No pull up/ no pull down = floating Pull up to 5 Vdc = 5 Vdc Pull down = 0 Vdc Pull up/ pull down = 2.5 Vdc
Voltage working ranges	Programmable (see specific data sheets for ranges).

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36*	Modules will survive with full functionality if input voltage does not exceed 36 Vdc.
Rising voltage threshold	Vdc	2.80	4.15	A digital input is guaranteed to be read as high if the voltage is greater than 4.15 Vdc.
Falling voltage threshold	Vdc	1.01	2.77	A digital input is guaranteed to be read as low if the voltage is less than 1.01 Vdc.

Inputs/outputs types and specifications

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Time to change state in response to step input	ms		1.5	Input change from maximum to minimum—add to debounce time.
Input impedance				
Input voltage < 5.7 Vdc	kΩ			233 nominal—no pull up or pull down pin configuration.
Input impedance				
Input voltage < 5.7 Vdc	kΩ			14.1 nominal—pull up or pull down pin configuration.
Input impedance				
Input voltage ≥ 5.7 Vdc	kΩ			14.1 nominal—all pin configurations.

* MC050-055/05B input voltage maximum is limited to 16 Vdc.

AIN

Analog inputs (AIN) specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin*	Vdc	0	36**	
0 to 5 Vdc range maximum discernible voltage	Vdc	5.21	5.30	5.26 is typical.
0 to 36 Vdc range maximum discernible voltage	Vdc		31.70	
Precision	mV		1.28	
Input impedance	kΩ	206	236	Depends on pin configuration.

* Maximum allowed voltage on fixed range analog input pins (CAN shield) is 25 Vdc.

** MC050-055/05B input voltage maximum is limited to 16 Vdc.

Analog input offset

Module analog input offset error can be 80 counts out of 4096 (12 bit resolution). Therefore, the minimum voltage that a module will read at the 0 to 5.25 Vdc range is 105 mV. The minimum voltage that a module will read at the 0 to 36 Vdc range is 703 mV.

The input offset error is a function of component tolerances and can vary from one module to the next. When an input value is used in an algorithm where the offset error could impact the control strategy, the way the signal is acquired and the need to calibrate should be considered.

A/D refresh rate

Analog to Digital (A/D) refresh rates for individual PLUS+1® modules are listed in the following table. A/D channels are sampled at 25 kHz and 64 samples are taken to build an average value. This results in a refresh rate of 2.56 ms for channels directly measured. All internal current feedback channels are refreshed at the 2.56 ms rate.

Some PLUS+1® module A/D channels are shared. Each of the shared channels have eight multiplexed analog inputs. Each multiplexed input is serviced every 20.48 ms. Update rates for specific analog input pins are found in the following table. Update rates for input expander modules are dependent on the CAN message frequency selected in the application program.

Inputs/outputs types and specifications

A/D refresh rates for PLUS+1® modules

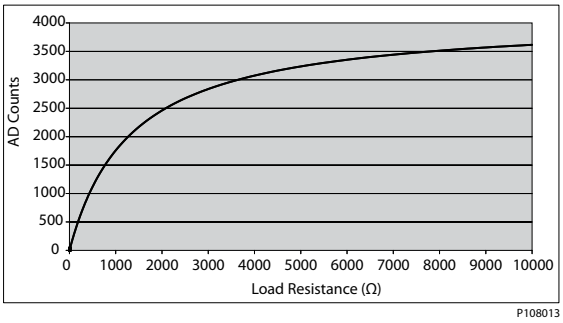
PLUS+1® module	A/D refresh rate
MC012-010/012	All: 2.56 ms
MC012-026/029	All: 2.56 ms
MC018-010/012	All: 2.56 ms
MC024-010/011/012/014	All: 2.56 ms
MC024-020/021/022/024	C1p10 to C1p12: 7.68 ms Remaining pins: 2.56 ms
MC024-500	All: 2.56 ms
MC038-010	C1p08, C1p14, C1p17 to C1p20, C1p24 to C1p27, C1p36 to C1p38: 20.48 ms C1p05, C1p10 to C1p12: 2.56 ms
MC050-010/012	C1p05, C1p08, C1p14 to C1p19, C1p22 to C1p30, C1p34 to C1p36: 20.48 ms C1p02: 2.56 ms
MC050-020/022	C1p05, C1p22, C1p25 to C1p32, C1p39, C1p40: 20.48 ms C1p02, C1p08, C1p18, C1p19, C1p23, C1p24: 2.56 ms
MC050-055/05B	C1p05, C1p13 to C1p29, C1p31 to C1p39, C1p41 to C1p45: 20.48 ms C1p46 to C1p49: 2.56 ms
MC088-015/01B/315	C1p05, C1p08, C1p14 to C1p19, C1p22 to C1p30, C1p34 to C1p36, C1p47 to C1p50 , C2p09 to C2p11, C2p35 to C2p38: 20.48 ms
IOX012-010	Refresh rate is a function of CAN message frequency
IOX024-020	Refresh rate is a function of CAN message frequency
IX012-010	Refresh rate is a function of CAN message frequency
IX024-010	Refresh rate is a function of CAN message frequency

AIN/Temp/Rheo; Din/AIN/FreqIN/Rheo

Analog/Temperature/Rheostat (AIN/Temp/Rheo); Digital/Analog/Frequency/Rheostat (Din/AIN/FreqIN/Rheo).

When a PLUS+1® module input pin is configured in the temperature/rheostat mode, the input has a 1.33 kΩ pull up resistor to +5 Vdc. It will source up to 3.75 mA current to an external load (RL) which then can be measured. The equation for relating AD counts to a given load is: AD counts = (4096*RL) / (RL + 1330). This calculation is solved internally and the ohms value is available for the programmer. The following chart shows the relationship between AD counts and load resistance in ohms.

Rheostat inputs



Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Measured resistance	Ω	0	10000	

Inputs/outputs types and specifications

DIN/AIN/FreqIN; Din/AIN/FreqIN/Rheo

All modules except IX012-010, IX024-010.

Digital/Analog/Frequency(DIN/AIN/FreqIN); Digital/Analog/Frequency/Rheostat(Din/AIN/FreqIN/Rheo).

The characteristics of Digital/Analog/Frequency pins are GUIDE software controlled. The input can be digital, analog or frequency. Inputs can be pulled to 5 Vdc, pulled to ground, pulled to 2.5 Vdc, or no pull-up/pull-down.

General

Description	Comment
Response to input below minimum voltage	Non-damaging, non-latching; reading saturates to the low limit.
Response to input above maximum voltage	Non-damaging, non-latching; reading saturates to the high limit.
Expected measurement	Frequency (Hz)
	Period (0.1 µsec)
	Channel to channel phase shift (paired inputs . . .) (0.1 ms).
	PWM duty cycle (0.01%)—Duty cycle measurement only valid up to 5 kHz (FreqIN).
	xEdge count.
	Quadrature count (paired inputs driven from a quadrature encoder).
Pull up/pull down configuration	No pull down/ pull up is standard with pull up or pull down programmable; failure modes are detectable.

As with analog input pins, values in the following table assume software compensation for AD converter offset errors.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Frequency range	Hz	0	10000	In steps of 1 Hz.
Maximum discernable voltage (high range)	Vdc	34.62	35.91	35.3 Vdc is typical.
Maximum discernable voltage (middle range)	Vdc	5.18	5.33	5.26 Vdc is typical.
Maximum discernable voltage (low range)	Vdc	0.360	0.375	0.368 Vdc is typical.
Precision (high range)	mV	– –	8.62	
Worst case error (high range)	mV	– –	614	
Precision (middle range)	mV	– –	1.28	
Worst case error (middle range)	mV	– –	75	
Precision (low range)	µV	– –	89.7	
Worst case error (low range)	mV	– –	7.39	
Input impedance (pulled to 5 Vdc or ground, middle and low range)	kΩ	13.9	14.3	

Inputs/outputs types and specifications

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Input impedance (pulled to 2.5 Vdc middle and low range)	kΩ	7.17	7.37	
Input impedance (no pull ups, middle and low range)	kΩ	230	236	
Input impedance (pulled to 5 Vdc or ground, high range)	kΩ	13.0	13.4	
Input impedance (pulled to 2.5 Vdc high range)	kΩ	6.92	7.12	
Input impedance (no pull ups, high range)	kΩ	108	112	
Rising voltage threshold (high range)	Vdc	18.9	27.6	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Falling voltage threshold (high range)	Vdc	6.8	18.5	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Rising voltage threshold (middle range)	Vdc	2.92	4.12	A digital input is guaranteed to be read as high if the voltage is greater than 3.99 Vdc. These numbers also apply to frequency.
Falling voltage threshold (middle range)	Vdc	1.02	2.75	A digital input is guaranteed to be read as low if the voltage is less than 0.96 Vdc. These numbers also apply to frequency.
Rising voltage threshold (low range)	Vdc	0.197	0.298	A digital input is guaranteed to be read as high if the voltage is greater than 0.28 Vdc.
Falling voltage threshold (low range)	Vdc	0.071	0.192	A digital input is guaranteed to be read as low if the voltage is greater than 0.067 Vdc.

MC050-010 and MC050-018 pin C1p26 should not be configured as a FreqIN.

Recommendation is to not use pin C1p26 as a frequency input. If used, recommendation is to disable internal filtering and use filter inside the application instead.

DIN/AIN/FreqIN

IX012-010, IX024-010 modules.

Digital/Analog/Frequency (DIN/AIN/FreqIN).

The characteristics of Analog/Digital/Frequency pins are GUIDE software controlled. The input can be digital, analog or frequency. Inputs can be pulled to 5 Vdc, pulled to ground, or pulled to 2.5 Vdc. Analog to digital resolution is 10 bits.

As with analog input pins, values in the following table assume software compensation for the errors in the AD converter.

Inputs/outputs types and specifications

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Frequency range	Hz	0	10000	In steps of 1 Hz.
Maximum discernable voltage (high range)	Vdc	35.3	36	36 Vdc is typical.
Maximum discernable voltage (middle range)	Vdc	5.67	5.83	5.75 Vdc is typical.
Maximum discernable voltage (low range)	Vdc	0.440	0.456	0.448 Vdc is typical.
Minimum discernable voltage	Vdc	0	0.08	
Precision (high range)	mV	– –	36.5	
Worst case error (high range)	mV	– –	614	
Precision (middle range)	mV	– –	5.62	
Worst case error (middle range)	mV	– –	75	
Precision (low range)	µV	– –	438	
Worst case error (low range)	mV	– –	7.39	
Input impedance (pulled to 5 Vdc or ground, middle and low range)	kΩ	13.9	14.3	
Input impedance (pulled to 2.5 Vdc middle and low range)	kΩ	7.17	7.37	
Input impedance (no pull ups, middle and low range)	kΩ	230	236	
Input impedance (pulled to 5 Vdc or ground, high range)	kΩ	10.3	10.7	
Input impedance (pulled to 2.5 Vdc high range)	kΩ	6.07	6.27	
Input impedance (no pull ups, high range)	kΩ	36.4	38.4	
Rising voltage threshold (high range)	Vdc	– –	– –	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Falling voltage threshold (high range)	Vdc	– –	– –	It is inadvisable to use the high range option when configuring the input as a digital or frequency input.
Rising voltage threshold (middle range)	Vdc	2.85	4.03	A digital input is guaranteed to be read as high if the voltage is greater than 4.03 Vdc. These numbers also apply to frequency.
Falling voltage threshold (middle range)	Vdc	1.15	2.59	A digital input is guaranteed to be read as low if the voltage is less than 1.15 Vdc. These numbers also apply to frequency.

Inputs/outputs types and specifications

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Rising voltage threshold (low range)	Vdc	0.22	0.31	A digital input is guaranteed to be read as high if the voltage is greater than 0.31 Vdc.
Falling voltage threshold (low range)	Vdc	0.090	0.20	A digital input is guaranteed to be read as low if the voltage is greater than 0.090 Vdc.

Potential for IX modules to not go online. If voltage is applied to an IX module input pin prior to the module being powered on, there is a possibility that the module CPU will not power up. The module is not damaged and will power up and operate normally once power is removed from the input pins. It is recommended that either the IX module's 5 Vdc sensor power be used to power sensors or that power is removed from the input pins until the module is powered up.

If the frequency goes to zero, the data will not decay over time, it will be updated once a new pulse is seen, or times out. It is possible to monitor the count of pulses to know when the frequency reading is updated.

DIN/AIN/4-20 mA IN

Digital/Analog/4-20 mA (DIN/AIN/4-20 mA IN).

Refer to *DIN/AIN/FreqIN* on page 12, for input properties when pins are configured as digital, analog or frequency. If the pin is configured to read current, the table below applies. When interfacing with sensors that transmit a 4 to 20 mA current signal, the positive lead of the transmitter is connected to battery voltage and the negative lead is connected to the PLUS+1® module pin. The current measuring configuration relies on the application program to provide over current protection.

The current measuring configuration is only available on MC088-XXX modules.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	
Minimum input current	mA	3	4	
Maximum input current	mA	20	24	
Precision	µA		5.86	

Outputs

Output types

- Digital (DOUT)
- Digital/PVG valve reference power (DOUT/PVGpwr)
- High current digital (HDOUT)
- Pulse width modulated (PWM/DOUT/PVGOUT)
- High current (6 A) pulse width modulated (HPWMOUT/DOUT)
- High current (10 A) pulse width modulated (HPWMOUT/DOUT)

Inputs/outputs types and specifications

Output pins available on individual PLUS+1® modules

PLUS+1 Module	DOUT (2A)	DOUT (3 A)	HDOUT (6 A)	DOUT/PVGpwr (3 A)	PWMOUT/ DOUT/PVGOUT (3 A)	HPWMOUT/ DOUT (6 A)	HPWMOUT/ DOUT (10 A)
MC012-010/012					2		
MC012-026/029					2		
MC018-010/012	4				2		
MC024-010/011/ 012/014					4		
MC024-020/021/ 022/024					8		
MC038-010	2		3			3	5
MC050-010/012		3		3	10		
MC050-020/022		6		2	6		
MC050-055/05B		1			2		
MC088-015/01B		13	6	3	10		
IOX012-010					2		
IOX024-020					8		
OX012-010					6		
OX024-010		4		2	10		

PLUS+1® modules feature user-configurable output pin parameters. Output pin parameters are configured using PLUS+1® GUIDE templates.

Refer to module data sheets for maximum output current ratings of individual modules and MC038-010 and MC088-015/01B power planes. The total output current for any PLUS+1® module must not exceed the maximum allowable current specified in the module data sheet. In the case of MC038-010 and MC088-015/01B modules, both the total output current for an individual power plane and the total output for the module must not exceed the limits specified on the module data sheets.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. The module will be powered up if battery voltage is applied to the module's output pin. To protect against unintended movement, secure the machine.

Caution

Warranty will be voided if module is damaged by significant current driven back through an output pin.

DOUT and DOUT/PVEpwr

Digital (DOUT) and Digital/PVG Reference Power (DOUT/PVEpwr).

Digital outputs can source up to 3 A. The exception is MC038-010 controller, DOUT pins are limited to 2 A.

Inputs/outputs types and specifications

- Current outputs for MC050-010, MC050-020, MC088-015, and OX024-010 module
- DOUT and DOUT/PVG Pwr pins are pair limited and a function of temperature.

  Output per pair is: 6 A maximum at 25 C [77 F]. Output per pair is 4 A maximum at 70° C [158° F]
- MC050-010 pairs are: C1p31 and C1p32, C1p33 and C1p34, C1p35 and C1p36
- MC050-020 pairs are: C1p33 and C1p34, C1p35 and C1p36, C1p37 and C1p38, C1p39 and C1p40
- MC088-015 pairs are:

  Power plane C2p35: C1p31 and C1p32, C1p33 and C1p34

  Power plane C2p36: C1p35 and C1p36

  Power plane C2p37: C2p1 and C2p7, C2p2 and C2p3, C2p4 and C2p5, C2p30 and C2p33

  Power plane C2p38: C2p6 and C2p12
- OX024-010 pairs are: C1p6 and C1p7, C1p8 and C1p9, C1p10 and C1p11
- Example: at a module temperature of 70° C [158° F], if C1p31 is sourcing 2.5 A, the most current that can be sourced on its paired pin C1p32 is 1.5 A

General

Description	Comment
Configuration	Sourcing only.
Type	Linear switching.
Short circuit to ground protection	Non-damage, current/thermal limit with status indication; automatic latch off /resume.
Open circuit detection	Fault indication provided. The GUIDE Pin Status requires a load of 500 mA to be connected or an open fault will be declared.
Parallel operation	Digital outputs from the same module are capable of being connected together such that the net current rating is the sum of the individual ratings; timing is resolved by the operating system; diagnostic capability is maintained.
Shut off	Processor control with hardware WatchDog override.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	Reference warning statement in topic *HDOUT* on page 16.
Output voltage, energized state	Vdc	Vbatt-1.0	Vbatt	Over all load conditions.
Output voltage, off state	Vdc	0	0.1	At Rload=200 Ω
Output current range for a status bit to read OK	A	0.5	3	Refer to the note above regarding pair.

Do not connect a digital output to battery+ (back drive) without a series diode.

HDOUT

High Current Digital (HDOUT)

High current digital outputs can source up to 6 A.

Inputs/outputs types and specifications

General

Description	Comment
Configuration	Sourcing only.
Type	Linear switching.
Short circuit to ground protection	Non-damage, current/thermal limit with status indication; automatic latch off/resume.
Open circuit detection	Status indication provided. The GUIDE pin status requires a load of 1000 mA to be connected or an open status will be declared.
Parallel operation	Digital outputs from the same module are capable of being connected together such that the net current rating is the sum of the individual ratings: timing is resolved by the operating system and diagnostic capability is maintained.
Shut off	Processor control with hardware Watchdog override.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36	See caution statement below.
Output voltage, energized state	Vdc	Vbatt-1.0	Vbatt	Over all load conditions.
Output voltage, off state	Vdc	0	0.1	At Rload=200 Ω
Output current range for status bit to read OK	A	1	6	See pair comment above.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. DOUT and HDOUT digital outputs do not have an internal feedback to the PLUS+1® module kernel. To protect against unintended movement, if the application requires fault detection, an external feedback using an AIN configured pin must be used. External feedback is required if the actual output is to be read by the PLUS+1® Service Tool.

All other output types have internal feedback to the PLUS+1® module kernel that provide pin fault and status information that can be read directly by the application and the PLUS+1® Service Tool.

PWMOUT/DOUT/PVGOUT

Pulse Width Modulated (PWMOUT/DOUT/PVGOUT).

All PLUS+1® module proportional outputs are Pulse Width Modulated (PWM). PWM frequency is software adjustable using GUIDE. A low frequency dither may also be added with software to some outputs (see individual module API specifications for PWM outputs that support dither). There are two modes of PWM operation: open loop and closed loop (current control).

In open loop mode, current can be sourced or sunk (all modules are limited to 8 amps sinking), but the output is a PWM duty cycle. Current feedback may be monitored in open loop mode, but the output is a constant voltage, not a constant current. PVG valves may be driven with open loop PWM.

In closed loop mode, current is sourced and a constant current is maintained by the module's operating system using internal current feedback. Load impedance must not exceed 65 ohms.

In closed loop mode, the maximum current is limited by measuring the feedback current. There is no thermal protection. If the maximum current is exceeded, the controller kernel will shut down the output and latch it. The kernel also limits how quickly the output can be repowered (250 ms). The output cannot be reset until the command goes to 0 or False (if configured as a digital output).

Inputs/outputs types and specifications

Proportional outputs that are used as a digital sinking output have a potential for a leakage current of up to 5 mA when off.

Refer to individual module data sheets for the maximum allowable output current for each PLUS+1® module.

General

Description	Comment
Configuration	Sourcing or sinking.
Type (Linear vs. PWM)	PWM
Operating modes	Programmable: closed loop current or open loop voltage (duty cycle).
Dual coil PCPs	Compensated for induced currents in a non-driven coil (closed loop mode).
Short circuit to ground	Output fully protected against damage and fault detected.
Mode selection (current or voltage) and full scale current ranges	Programmable.

Do not connect a digital output to battery+ (back drive) without a series diode.

PLUS+1 PWM output circuits are not designed to be used as inputs. Output current feedback readings should be used for fault checking only.

Warning

Unintended movement of the machine or mechanism may cause injury to the technician or bystanders. The module will be powered up if battery voltage is applied to the module's output pin. To protect against unintended movement, secure the machine.

Caution

Warranty will be voided if module is damaged by significant current driven back through an output pin.

Specifications

Description	Units	Minimum	Maximum	Comment
Full scale proportional current output	mA	10	3000	The current may accidently be exceeded in open loop mode. If the current exceeds the trip point, the output will be latched off.
Output voltage, 100% duty cycle	Vdc	0	Vbatt-1	
Output resolution of 3 A	mA		0.25	
Repeatability of full range	% of full scale		0.5	
Absolute accuracy of full range	% of full scale		0.5	
Output settling time	ms		100	Depends on load characteristics.
PWM frequency	Hz	33	4000	Some pins have a fixed frequency, consult module application program interface (API).
Dither frequency	Hz	33	250	Increased in steps, see module API.

Inputs/outputs types and specifications

Specifications (continued)

Description	Units	Minimum	Maximum	Comment
Dither amplitude	A	0	0.5	Increased in steps, see module API.
Over-current trip point	A	5	5.25	There is over-current protection built into each output driver. If the instantaneous current exceeds the trip point, the driver is latched off. GUIDE application software can reset the latch and attempt to drive current again.

HPWMOUT/DOUT

High Current Pulse Width Modulated (HPWMOUT/DOUT).

High current proportional outputs are unique to the MCO38-010 controller. These outputs are PWM, with PWM frequency user-configurable using PLUS+1® GUIDE.

The MC038-010 has two types of high current PWM outputs:

- Paired bi-directional PWMs (10 A) that can be configured as either H bridges or independent outputs.
- Sourcing only PWMs (one 10 A and six 6 A).

See the product data sheet and API documents for pair assignments.

All high current proportional outputs are operated as open loop. The controller kernel does, however, monitor current for circuit protection, but there is no current feedback to the application. The output is a constant voltage and not a constant current. PWM outputs are hardware protected from short or over current.

Specifications

Description	Units	Minimum	Maximum	Comment
Over-current trip point, 6 A	A		12	Temperature dependent.
Over-current trip point, 10 A	A		18	Temperature dependent.
PWM frequency	Hz	33	4000	

MC038-010, MC088-XXX output pin power supply

The output pin power supply design of the MC038-010 and MC088-XXX controllers is different from that of other PLUS+1® modules. MC038-010 and MC088-XXX controllers have discrete power supply planes for output pins and a separate dedicated power supply for the DSP. Each output pin is associated with a specific power supply plane. Refer to the controller data sheets for a map of outputs and their associated power plane.

The controller DSP will be powered if power is supplied to any one of the controller's power planes.

Controller Area Network (CAN) specifications

CAN ports

System design

All PLUS+1® modules have CAN ports that conform to CAN 2.0B specifications, including CAN shield.

CAN1 port and CAN2 port on MC050-155/15B controllers cannot be used to download PLUS+1® GUIDE application programs.

Terminating resistor

Each end of the main backbone of the CAN bus must be terminated with an appropriate resistance to provide correct termination of the CAN_H and CAN_L conductors. This termination resistance should be connected between the CAN_H and CAN_L conductors.

Specifications

Description	Units	Minimum	Maximum	Nominal	Comment
Resistance	Ω	110	130	120	Minimum power dissipation 400 mW (assumes a short of 16 Vdc to CAN_H).
Inductance	µH		1		

CAN Bus installation

Total bus impedance should be 60 Ω.

The CAN transceiver will be damaged by any voltage outside of allowable range, even with a very short pulse.

If using shielded cable, the shield must be grounded to the machine ground at one point only; preferably at the mid-point of the CAN bus. Each PLUS+1® module CAN shield pin must be connected to the cable shield.

Expansion module CAN Bus loading

System designers incorporating PLUS+1® expansion modules in their applications should be aware of PLUS+1® CAN bus loading and controller memory usage during system design. Each expansion module is associated with a PLUS+1® controller and uses part of the controller's memory resources for inter-module communications. The table below can be used to estimate system CAN bus loading and the memory impact of I/O modules on their associated controller.

Estimated usage of memory and communication resources

Description	IX012-010	IX024-010	OX012-010	OX024-010	IOX012-010	IOX024-20
Estimated module bus load (using default update and 250K bus speed)	4%	10%	11%	27%	11%	27%
Estimated module bus load (using 70 ms updates and 250K bus speed)	2%	5%	3%	8%	4%	8%

Controller Area Network (CAN) specifications

Estimated usage of memory and communication resources (continued)

Description	IX012-010	IX024-010	OX012-010	OX024-010	IOX012-010	IOX024-20
RAM usage on MC012-XXX	9%	12%	9%	14%	9%	17%
RAM usage on MC024-010	9%	12%	9%	14%	9%	17%
RAM usage on MC050-010, MC050-020	1%	1%	1%	2%	1%	2%
RAM usage on MC050-055	1%	1%	1%	2%	1%	0%
ROM usage on MC012-XXX	8%	11%	12%	18%	10%	19%
ROM usage on MC024-010	8%	11%	12%	18%	10%	20%
ROM usage on MC050-010, MC050-020	3%	4%	4%	6%	3%	8%
ROM usage on MC050-055	3%	4%	4%	6%	3%	8%

Product ratings

Power

Module supply voltage/Maximum current ratings

PLUS+1® modules are designed to operate with a nominal 9 to 32 Vdc power supply. The modules will survive with full functionality if the supply voltage remains below 36 Vdc.

Specifications

Description	Units	Minimum	Maximum	Comment
Allowed voltage at pin	Vdc	0	36**	
Allowed module current	A	0		Consult module data sheets for maximum allowable current.

** MC050-055/05B input voltage maximum is limited to 16 Vdc.

Caution

PCB damage may occur. To prevent damage to the module all module power supply + pins must be connected to the vehicle power supply to support advertised module maximum output current capacity. DO NOT use module power supply + pins to supply power to other modules on a machine.

MC038-010 power supply

The MC038-010 controller's power supply design recommendations must be followed:

- Power supply to MC038-010 controller's output power planes (C1-p36 to C1-p38) must be wired directly to the vehicle battery and the wiring runs must be kept as short as possible.
- Power supply to the controller's DSP (C1-p2) must be wired separately from the power supply to the controller's output power planes.
- Do not connect any other PLUS+1® controllers to the power supply to MC038-010 controller's output power planes.

MC038-010 sleep mode

Sleep mode is unique to the MC038-010 controller. This feature gives OEM designers the ability to implement automotive-like features in their machine control system design. If the sleep mode feature is not implemented, this controller has the same operating characteristics as any other PLUS+1® controller.

When used as a sleep mode controller, supply power to the MC038-010 is connected directly to the battery. Sleep mode initiation is defined by the controller's application software: PLUS+1® GUIDE programmers define the conditions under which the controller is to put to sleep. When in sleep mode, controller outputs are set to zero, sensor power supply is off and the controller consumes a small amount of current.

Controller sleep mode current consumption

Supply voltage	Sleep mode current consumption
12 Vdc	0.14 mA
24 Vdc	0.28 mA

Battery power must be supplied to designated wake-up digital inputs, since the controller's 5 Vdc regulated power supply is not available when the controller is in sleep mode.

Product ratings

Either of two conditions will wake up the controller:

- Switching any of the designated wake-up digital inputs (DIN) in the GUIDE application, to high
- Cycling all input power to the controller

The following input pins may be designated as wake-up digital inputs:

- DIN (C1p06, C1p07)
- DIN/AIN (C1p14, C1p17 to C1p20, C1p24 to C1p27

Specifications

Description	Units	Minimum	Maximum	Comment
Wake-up pin threshold	Vdc	2	36	To wake up by cycling input power.
Wake-up pin threshold	Vdc	4.5	36	To wake up by digital input.
Wake-up time delay	mSec	250	500	

Sensor power supply ratings

PLUS+1® modules that support sensor inputs are provided with dedicated regulated sensor power supply and ground pins. Refer to individual product data sheets for sensor power supply current ratings. The sensor power is nominally 5 Vdc, unless otherwise noted on the product data sheet.

General

Description	Comment
Short circuit to ground	Output is not damaged and fault is detected.
Short circuit to battery +	Output is not damaged and fault is detected.

Specifications (all modules except MC050-055/05B)

Description	Units	Minimum	Maximum	Comment
Output short circuit voltage	Vdc		36	
Output voltage	Vdc	4.88	5.12	
Output current	mA			Refer to individual data sheets for sensor power supply ratings.
Output Load Capacitance	µF		10	
Hold up time after power loss	m s	5	15	

MC050-055/05B controllers feature two additional levels of regulated power: 1.6 Vdc and 3.3 Vdc. The PLUS+1® GUIDE application developer can detect open and short digital inputs, when these power supplies are used in conjunction with DIN/AIN inputs.

Specifications (MC050-055/05B)

Description	Units	Minimum	Maximum	Comment
Output short circuit voltage	Vdc		36	
Output voltage, sensors	Vdc	4.88	5.12	Sensor power supply drops below minimum if controller power supply is less than 9 Vdc.
Output voltage, DIN diagnostics	Vdc	1.54	1.66	Nominal 1.6
Output voltage, DIN diagnostics	Vdc	3.00	3.60	Nominal 3.3

Product ratings

PVG valve power supply

DOUT/PVGpwr pins can provide the battery supply voltage required by Danfoss PVG valve electronics for those control strategies requiring application software control of the valve power source.

When enabled, the DOUT/PVGpwr pin passes battery (reference) voltage to the PVG valve electronics. One DOUT/PVGpwr pin can power up to 3 PVG valves. Refer to individual module API documents for PVG power pin characteristics.

EEPROM write/erase

Ratings

To prevent unexpected memory writes, ensure memory with a high number of read/write cycles is either U32 or S32 data types.

Specifications

Description	Minimum	Maximum	Comment
EEPROM write/erase cycles (all modules except IX012-010, IX024-010)	1 million		Minimum valid over entire operating temperature range.
EEPROM write/erase cycles (IX012-010, IX024-010)	10,000		Minimum valid over entire operating temperature range.
FRAM write/erase cycles (all extended memory modules-MC0XX-XX8)	100 trillion		Minimum valid over entire operating temperature range.

EEPROM used in PLUS+1® controllers is rated for 1 million read/write cycles per sector. Sector size is 32 bits. When a value is written to EEPROM, all 32 bits in a particular sector are always written, regardless of the size of the size of the saved value. If the value being saved in a sector is less than 32 bits (such as. U8, S16, BOLL, etc) adjacent bits in the same EEPROM sector are rewritten with their previous value. The implication of this memory property is that if two values are being written to the same memory sector, the useful life of the sector is determined by the value being written most frequently. If that value exceeds 1 million read/write cycles, all values in the sector may be compromised if the useful life is exceeded.

Vault memory

Some variants of PLUS+1® modules have 2 Mbyte of serial flash vault memory (also referred to as *application logging memory*).

Application developers can use this memory to log machine event data and use the PLUS+1® Service Tool to extract the logged data. As there is no real time clock on PLUS+1® modules, vault memory is not time stamped.

Accessing non-volatile or application log memory can delay the service tool scan.

FRAM memory

Any of the PLUS+1® extended memory controllers use FRAM memory. FRAM has a write endurance of over 100 trillion cycles. This increased write endurance is particularly ideal for datalogging.

Accessing non-volatile or application log memory can delay the service tool scan.

Product ratings

Environmental testing criteria

General product ratings

Description	Units	Minimum	Maximum	Comment
Operating temperature	˚C [˚F]	-40 [-40]	70 [158]	Maximum operating temperature for MC012-026/029 modules is 105° C (221° F).
Storage temperature	˚C [˚F]	-40 [-40]	85 [185]	Maximum storage temperature for MC012-026/029 modules is 105° C (221° F).
Allowable module supply voltage	Vdc	9	36*	Minimum allowable supply voltage for the MC038-010 module CPU power pin is 6 Vdc.
Module sensor supply voltage	Vdc	4.8	5.2	Sensor voltage drops below the minimum value if module supply voltage < 9 Vdc. Exception for MC050-055/05B and MC024-01A, see *Sensor power supply ratings* on page 23.
Analog input voltage levels	Vdc		36*	
Allowable output load current (per pin)	A			See individual module date sheets.
Module allowable total output current	A			See individual module data sheets.
All modules Ingress Protection (IP) rating**				IP 67
All modules CE rating				CE compliant.

* MC050-055/05B input voltage maximum is limited to 16 Vdc.

** The PLUS+1® modules IP 67 rating is only valid when the module mating connector is in place and unused connector pin positions have sealing plugs installed.

PLUS+1® module environmental testing criteria

Climate environment

Description	Applicable standard	Comment
Storage temperature	IEC 60068-2-1, test Ab, IEC 60068-2-2 test Bb	
Operating temperature	IEC 60068-2-1, test Ab, IEC 60068-2-2 test Bd	
Thermal cycle	IEC 60068-2-2, test Na, IEC 60068-2-38 (partial)	
Humidity	IEC 60068-2-78, IEC 60068-2-30 test Db	Damp heat steady state and cyclic.
Degree of protection	IEC 60529	

Product ratings

Chemical environment

Description	Applicable standard	Comment
Salt mist	IEC 60068-2-58 test Kb	
Chemical resistance	ISO 16750-5	

Mechanical environment

Description	Applicable standard	Comment
Vibration	IEC 60068-2-6 test Fc, IEC6008-2-64 test Fh	
Bump	IEC 60068-2-29 test Eb	
Shock	IEC 60068-2-27 test Ea	
Free fall	IEC 60068-2-32 test Ed	

Electrical/electromagnetic

Description	Applicable standard	Comment
EMC emission	ISO 13766, SAE J1113-13	Electromagnetic compatibility for earth moving machinery.
EMC immunity	ISO 13766	Electromagnetic compatibility for earth moving machinery.
Electrostatic discharge	EN 60-1 000-4-2	
Auto electrical transients	ISO 7637-2, ISO 7637-3	
Short circuit protection	Danfoss test	Inputs and outputs survive continuous short circuit. Normal function resumes when short is removed.
Reversed polarity protection	Danfoss test	Survives reverse polarity at supply voltage for at least five minutes.

Modules housing

PLUS+1® modules housing features a snap together assembly that is tamper-proof. Once assembled at the factory, the housing cannot be opened for service.

Opening the modules housing will void the factory warranty.

Product installation and start-up

Mating connectors

PLUS+1® modules use DEUTSCH connectors. Danfoss has assembled a mating connector kit, referred to as a bag assembly, for the 12, 24, 38, 50, and 88 pin module housings. Mating connector bag assembly ordering information is found in the product data sheet for each module.

DEUTSCH mating connector part information

Description	12 pin module	18 pin module	24 pin module	38 pin module	50 pin module	88 pin module
Crimp tool	HDT48-00(solid contacts)(20 to 24 AWG)	HDT48-00(solid contacts)(16 to 20 AWG)	HDT48-00(solid contacts)(20 to 24 AWG)	— —	HDT48-00(solid contacts)(20 to 24 AWG)	HDT48-00(solid contacts)(20 to 24 AWG, 12 to 14 AWG)
	DTT20-00(stamped contacts) (16 to 20 AWG)		DTT20-00(stamped contacts) (16 to 20 AWG)	DTT20-00(stamped contacts) (16 to 20 AWG)	DTT20-00(stamped contacts) (16 to 20 AWG)	
Contacts	Solid: 0462-201-2031 (20 to 24 AWG)	Solid: 0462-201-1631(16 to 20 AWG)	Solid: 0462-201-2031 (20 to 24 AWG)	Stamped: 0462-203-12141(10 to 14 AWG) 1062-20-0144(16 to 20 AWG)	Solid: 0462-201-2031 (20 to 24 AWG)	Solid: 0462-201-2031 (20 to 24 AWG)
	Stamped: 1062-20-0144 (16 to 20 AWG)		Stamped: 1062-20-0144(16 to 20 AWG)		Stamped: 1062-20-0144(16 to 20 AWG)	Solid: 0462-201-12141 (12 to 14 AWG)
						Stamped: 1062-20-0144(16 to 20 AWG)
Connector plug	Gray A-Key DTM 06-12SA	DT16-185B-K004	Gray A-KeyDTM 06-12SA Black B-Key DTM 06-12SB	DRC26-38S01-P017	DRC26-50S01	DRC26-50S01DRC26-38S01-P017
Wedge	WM-12S	Not required	WM-12S	Not required	Not required	Not required
Strip length	3.96 to 5.54 mm[0.156 to 0.218 in]	6.35 to 0.792 mm[0.250 to 0.312 in]	3.96 to 5.54 mm[0.156 to 0.218 in]	6.43 to 0.79 mm[0.253 to 0.031 in]	3.96 to 5.54 mm[0.156 to 0.218 in]	20 to 24 AWG: 3.96 to 5.54 mm[0.156 to 0.218 in]
						12 to 14 AWG: 6.43 to 0.79 mm[0.253 to 0.031 in]
Rear sealmaximum insulation OD	3.05 mm [0.120 in]	3.05 mm [0.120 in]	3.05 mm [0.120 in]	4.32 mm [0.17 in]	2.41 mm [0.095 in]	20 to 24 AWG: 2.41 mm [0.095 in]
						12 to 14 AWG: 4.32 mm [0.17 in]
Sealing plugs	0413-204-2005	114017	0413-204-2005	114017	0413-204-2005	0413-204-2005 , 114017

Product installation and start-up

Danfoss mating connector part information

Description	12 pin module	18 pin module	24 pin module	38 pin module	50 pin module	88 pin module
Mating connector bag assembly (20 to 24 AWG)	10100944	— —	10100945	— —	10100946	10105649
Mating connector bag assembly (16 to 20 AWG)	10102025	10102025	10102023	11027919	10102024	11071844

Danfoss crimp extraction tool part information

Description	Part number
Crimp tool for 20 to 24 AWG	10100745
Crimp tool for 16 to 20 AWG	10102028
Extraction tool Deutsch 114010; 12 AWG	11068808
Extraction tool Deutsch 0144-240-2005; 16 to 20, 20 to 24 AWG	10100744

PLUS+1® module mating connectors may be mated 10 times.

Recommended torque for the DEUTSCH mating connector retaining fastener on 38 and 50 pin connectors is 20 lb•in (2.26 N•m).

Product installation

Mounting

PLUS+1® 12, 24, 38, and 50 pin modules can be mounted in one of three ways:

- End (bulkhead) installation
- Up to 3 units stacked on one another
- Individually side mounted

MC018-XXX modules are designed for panel mounting only.

MC088-XXX modules are designed for bulkhead mounting only.

In each case, care must be taken to insure that the module connector is positioned so that moisture drains away from the connector. If the module is side or stack mounted, provide a drip loop in the harness. If the module is mounted vertically, the connector should be on the bottom of the module. Provide strain relief for mating connector wires.

Caution

Module damage may occur. Use caution when installing MC050-XXX modules. Due to the size of the mating connector wire bundle, it is possible to twist off the end cap of the module if excessive pressure is applied during the installation of harness strain relief.

Suggested fasteners and recommended installation torque

Mounting method	Recommended OD	Recommended torque
Bulkhead mount; multiple units stacked; single	6.0 mm (.25 in)	9.49 N•m (7 ft•lb)

Product installation and start-up

Machine diagnostic connector

It is recommended that a diagnostic connector be installed on machines that are controlled by PLUS+1® modules. The connector should be located in the operator's cabin or in the area where machine operations are controlled and should be easily accessible.

Communication (software uploads and downloads and service and diagnostic tool interaction) between PLUS+1® modules and personal computers is accomplished over the vehicle CAN network. The diagnostic connector should tee into the vehicle CAN bus and have the following elements:

- CAN +
- CAN -
- CAN shield

Grounding

Proper operation of any electronic control system requires that all control modules including displays, microcontrollers and expansion modules be connected to a common ground. A dedicated ground wire of appropriate size connected to the machine battery is recommended.

Hot plugging

Machine power should be off when connecting PLUS+1® modules to mating connectors.

Machine wiring guidelines

- Protect wires from mechanical abuse, run wires in flexible metal or plastic conduits.
- Use 85˚ C (185˚ F) wire with abrasion resistant insulation and 105˚ C (221˚ F) wire should be considered near hot surfaces.
- Use a wire size that is appropriate for the module connector.
- Separate high current wires such as solenoids, lights, alternators or fuel pumps from sensor and other noise-sensitive input wires.
- Run wires along the inside of, or close to, metal machine surfaces where possible, this simulates a shield which will minimize the effects of EMI/RFI radiation.
- Do not run wires near sharp metal corners, consider running wires through a grommet when rounding a corner.
- Do not run wires near hot machine members.
- Provide strain relief for all wires.
- Avoid running wires near moving or vibrating components.
- Avoid long, unsupported wire spans.
- Ground electronic modules to a dedicated conductor of sufficient size that is connected to the battery (-).
- Power the sensors and valve drive circuits by their dedicated wired power sources and ground returns.
- Twist sensor lines about one turn every 10 cm (4 in).
- Use wire harness anchors that will allow wires to float with respect to the machine rather than rigid anchors.

Caution

Unused pins on mating connectors may cause intermittent product performance or premature failure. Plug all pins on mating connectors.

Product installation and start-up

Machine welding guidelines

Warning

High voltage from power and signal cables may cause fire or electrical shock, and cause an explosion if flammable gasses or chemicals are present.
Disconnect all power and signal cables connected to the display before performing any electrical welding on a machine.

The following is recommended when welding on a machine equipped with electronic components:

- Turn the engine off.
- Remove electronic components from the machine before any arc welding.
- Disconnect the negative battery cable from the battery.
- Do not use electrical components to ground the welder.
- Clamp the ground cable for the welder to the component that will be welded as close as possible to the weld.

PLUS+1® USB/CAN Gateway

Communication (software uploads and downloads and service and diagnostic tool interaction) between PLUS+1® modules and a personal computer (PC) is accomplished using the vehicle's PLUS+1® CAN network.

The PLUS+1® CG150 USB/CAN gateway provides the communication interface between a PC USB port and the vehicle CAN bus. When connected to a PC, the gateway acts as a USB slave. In this configuration, all required electrical power is supplied by the upstream PC host. No other power source is required.

For gateway set-up information refer to the PLUS+1® GUIDE User Manual, *10100824*. For electrical specifications and connector pin details refer to the CG150 USB/CAN Gateway Data Sheet, *520L0945*.

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